

Environmentally Responsible Aviation: Propulsion Research to Enable Fuel Burn, Noise and Emissions Reduction

Dale Van Zante
ERA Project Engineer for Propulsion

and

Kenneth Suder
Turbomachinery and Turboelectric Systems Branch

Acknowledgements to:
ERA Project Manager
Fayette Collier, Ph.D., M.B.A.



Outline!



- ! Introduction"
- ! ERA Technical Challenges"
- ! ERA Phase II Integrated Technology Demonstrations"
 - ! Propulsion Integrated Technology Demonstrations"
- ! Potential Fleet Impacts"
- ! Concluding Remarks"

 C-2010-3452



National Aeronautics and Space Administration
Glenn Research Center at Lewis Field

Open Rotor technologies were studied during ERA Phase 1 in partnership with GE and FAA."

Introduction – System Level Metrics - Subsonic Transports!

Date for Technology Readiness Level=6	N+1 2015 Timeframe	N+2 2020 Timeframe	N+3 2025+ Timeframe
Noise (rel. to Stage 4)	-32 EPNdB	-42 EPNdB	-52 EPNdB
LTO NO _x Emissions (rel. to CAEP 6)	-60%	-75%	better than -75%
Aircraft Fuel Burn/ Energy Use (rel. 2005 Best in Class)	-33%	-50%	better than -50%

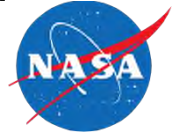
FAA CLEEN I FOCUS		FAA CLEEN II FOCUS
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NASA ERA FOCUS	NASA FIXED WING FOCUS
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AFRL AEROSPACE SYSTEMS DIRECTORATE RESEARCH FOCUS
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EUROPEAN FRAMEWORK RESERACH FOCUS

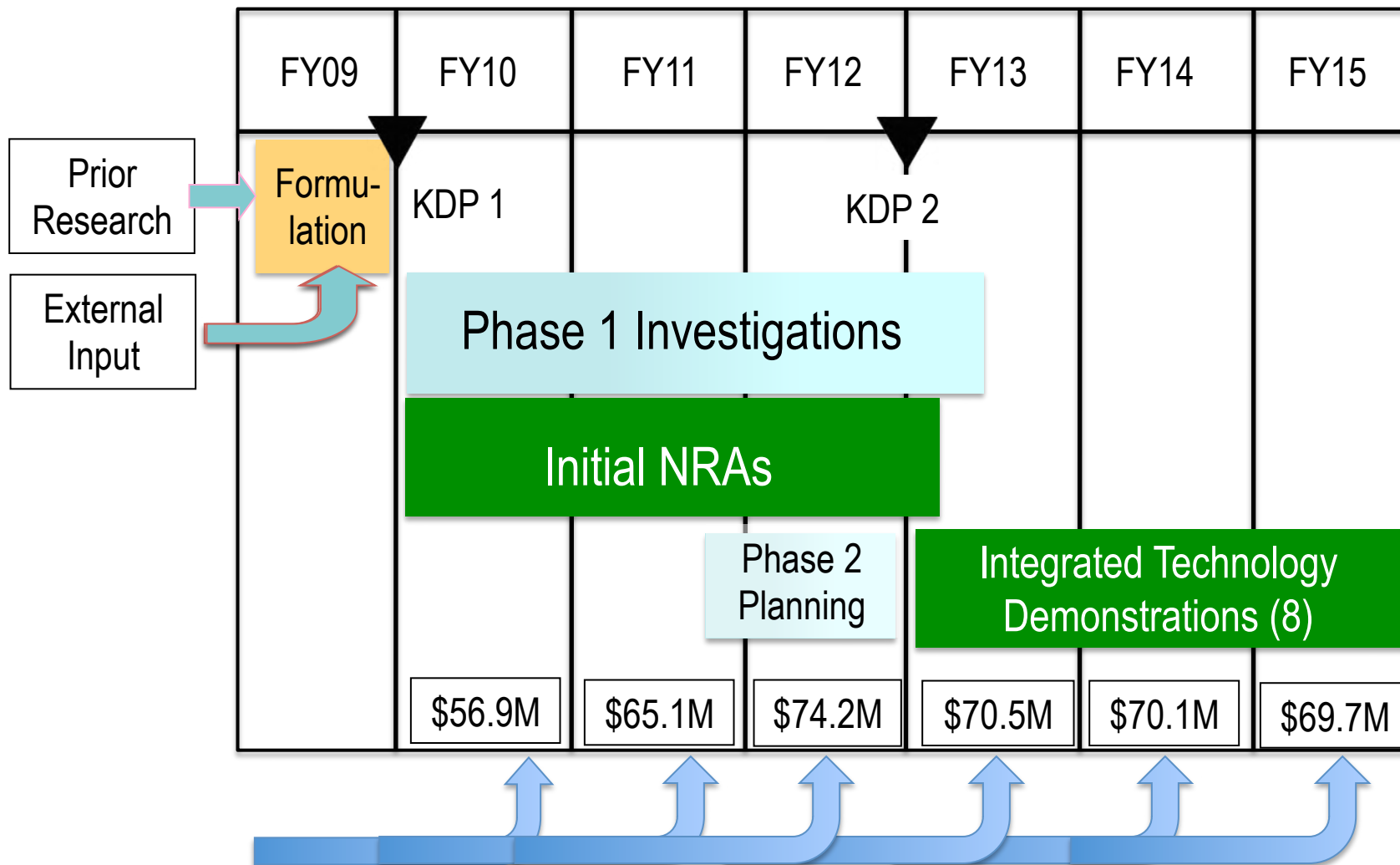
Introduction – Environmentally Responsible Aviation" Vision/Mission/Scope Aimed at N+2 Timeframe!



- !
- ! Vision"
 - ! expand the viable and well-informed trade space for commercial transport design decisions "
 - ! enable **simultaneous** realization of national noise, emissions, and performance goals"
- ! Mission"
 - ! Execute integrated technology demonstrations"
 - ! Partner w/Industry and transfer knowledge "
- ! Scope"
 - ! Mature technology for application in the 2020+ time frame"
 - ! Advance the state-of-the-art, reduce risk of application"
 - ! Perform system/subsystem research in relevant environments"

Introduction"

ERA Project Flow with Key Decision Points!



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CMC mixer nozzle work in ERA Phase 1 in partnership with Rolls-Royce and AFRL."

Decomposition of Sys Level Metrics to Technical Challenges !



TC1 Innovative Flow Control Concepts for Drag Reduction
–! Demonstrate drag reduction of 8 percent

TC2 Advanced Composites for Weight Reduction
–! Demonstrate weight reduction of 10 percent

TC3 Advanced UHB Engine Designs for Specific Fuel Consumption and Noise Reduction
–! Demonstrate UHB efficiency improvements to achieve 15% TSFC reduction,

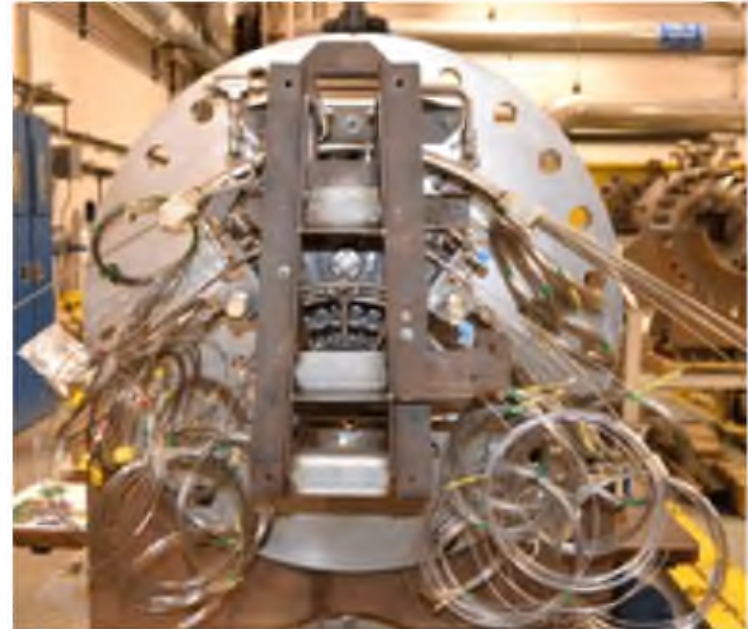
TC4 Advanced Combustor Designs for Oxides of Nitrogen Reduction
–! Demonstrate reductions of LTO NOx by 75 percent from CAEP6 and cruise NOx by 70 percent

TC5 Airframe and Engine Integration Concepts for Community Noise and Fuel Burn Reduction
–! Demonstrate reduced component noise signatures leading to 42 EPNdB to Stage 4

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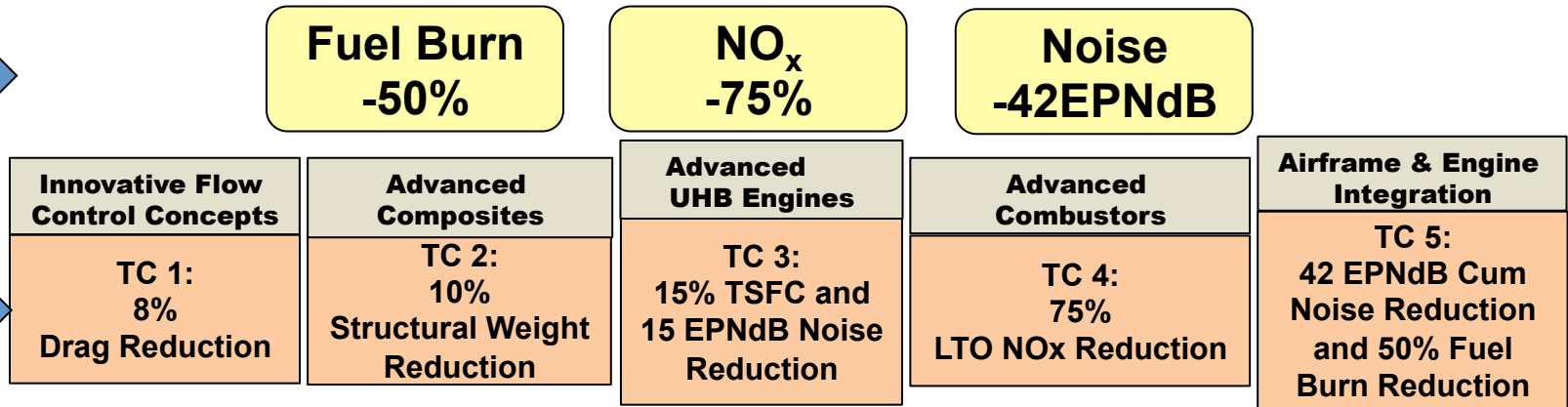


ERA Phase 1 combustor sector test in ASCR with partners GE and P&W."

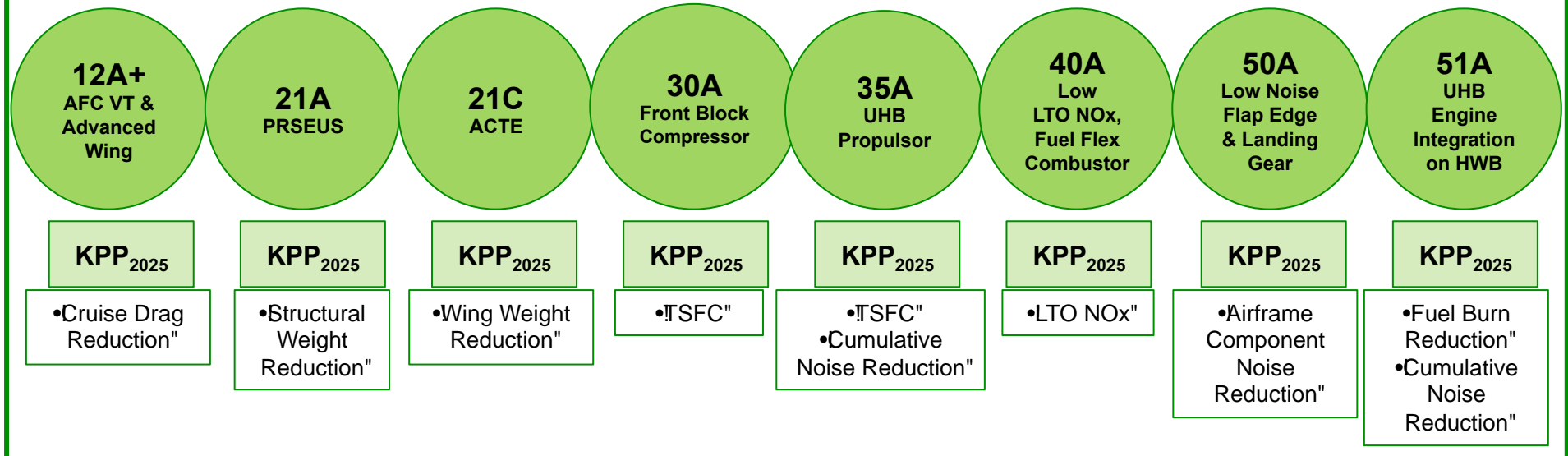
Goal Decomposition and Technology Selection!



! 2025!
Vehicle !
System !
Metrics!
! Technical!
Challenge!
! Progress
Indicators!



P2 Integrated Technology Demonstrations (TRL 4-6)



P1 Technology Development & Maturation

Airframe Technology" Integrated Technology Demonstrators!



**21A PRSEUS Assembled
multi-bay box in C-17
factory**

**21C Adaptive Compliant
Trailing Edge Flight
Demonstration**



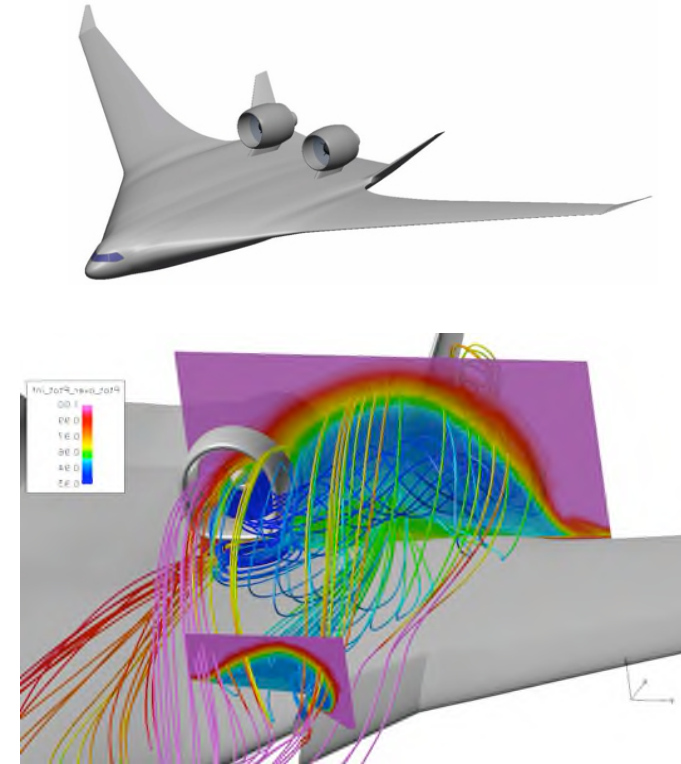
**12A+ AFC Vertical Tail and
Advanced Wing Flight Test**



Vehicle Systems Integration" Integrated Technology Demonstrators!



**50A Landing Gear & Flap Edge
Noise Reduction Flight Test**



**51A UHB Integration on a
Hybrid Wing Body**



Propulsion Technology! Integrated Technology Demonstrators! !

30A: Highly Loaded Front Block Compressor (GE)!

35A: 2nd Gen UHB Propulsor Integration (P&W and FAA)!

40A: Low NOx, Fuel Flexible Combustor Integration (P&W)!

Integrated Technology Demonstrator" Highly Loaded Front Block Compressor Demonstration!



Weight

Drag

TSFC

Noise

NOx

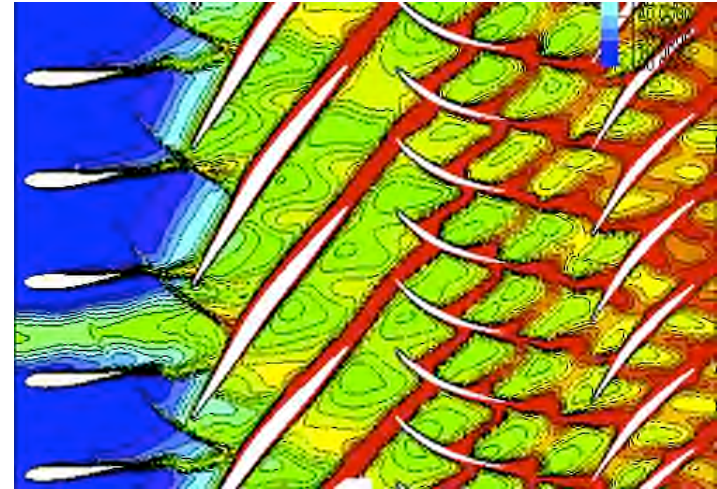
End TRL: 5!

Key Performance Parameters!

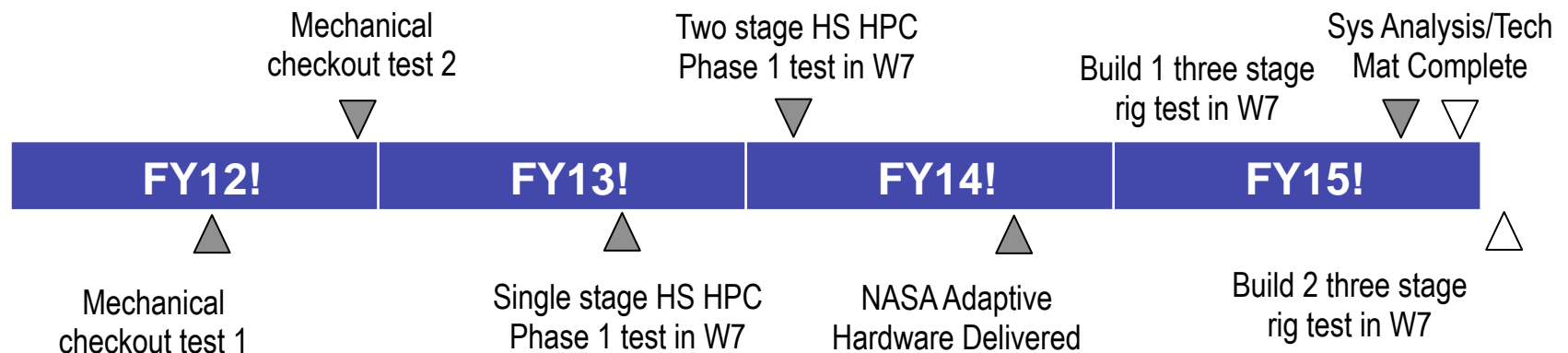
- ! Reduce TSFC by 2.5 percent"

Technology Insertion Challenges Addressed!

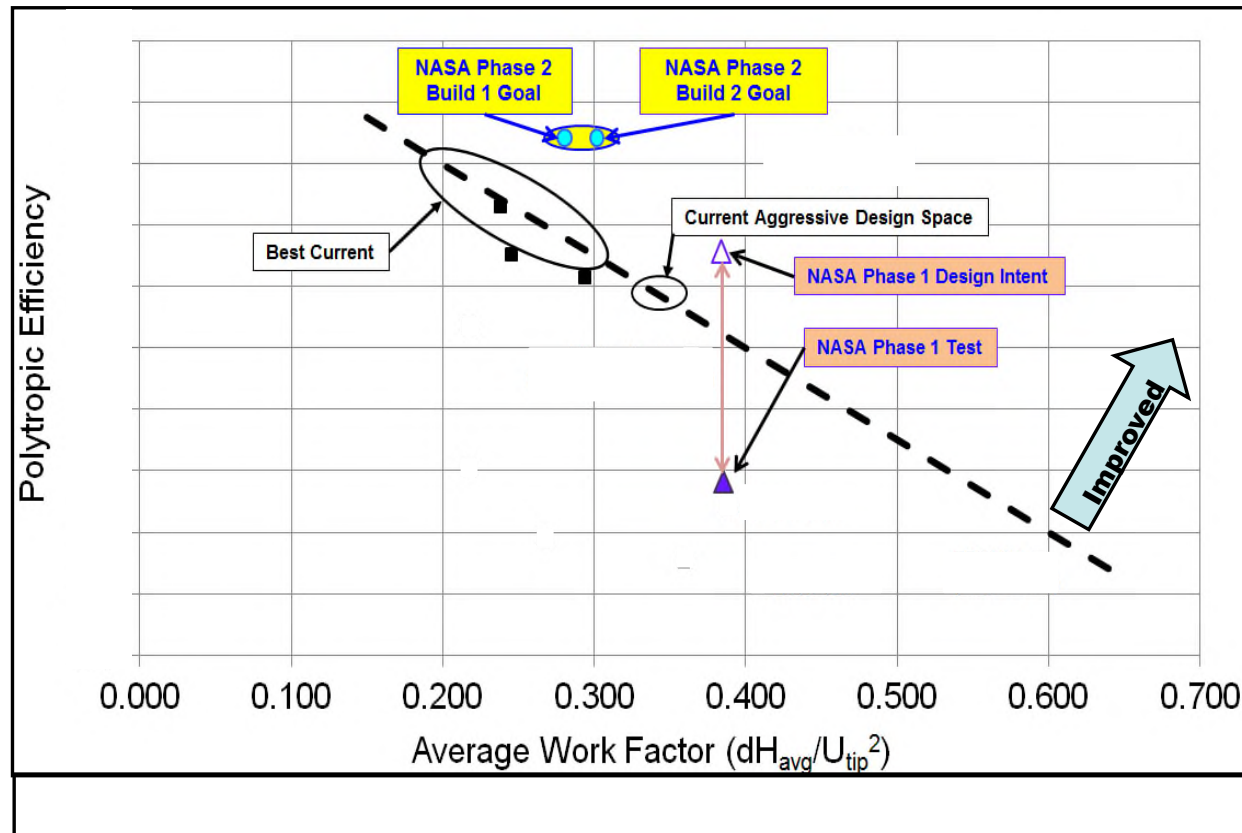
- ! Front block aerodynamic losses limit efficiency"
- ! Identify loss mechanisms and interaction effects of highly-loaded compressor stages"
- ! Trade-off OPR, Efficiency, and operability to optimize fuel burn"
- ! Establish part-speed operability margin"
- ! Integrated 1st 3 stages of HPC"



**Unsteady Interactions Predicted by
CFD: Entropy Plot – From Gorrell et al,
2005**



Integrated Technology Demonstrator" Highly Loaded Front Block Compressor Demonstration!



ITD30A had supply chain and hardware challenges.!
The intent of minimum success is still achievable as is the goal of 2.5% TSFC reduction for the technology.!

Integrated Technology Demonstrator" 2nd Generation UHB Propulsor Integration!



Weight

Drag

TSFC

Noise

NOx

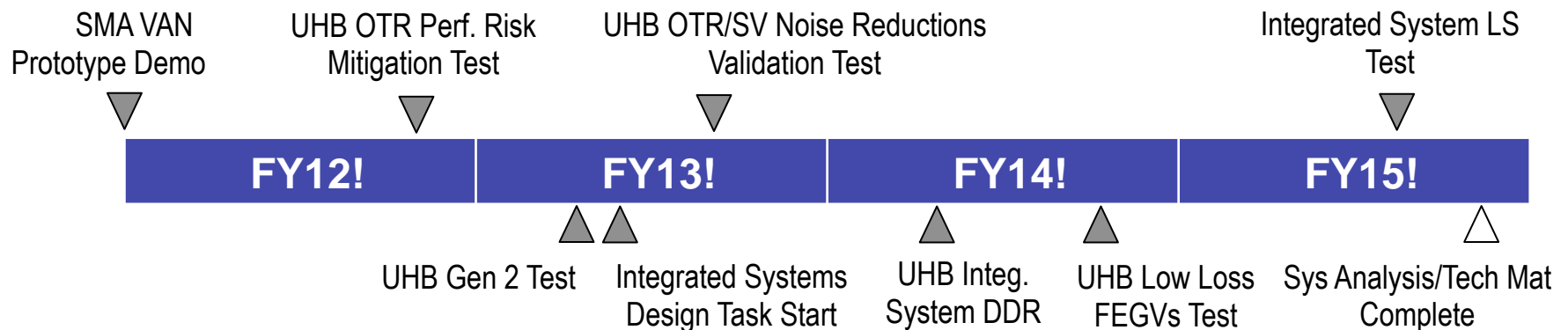
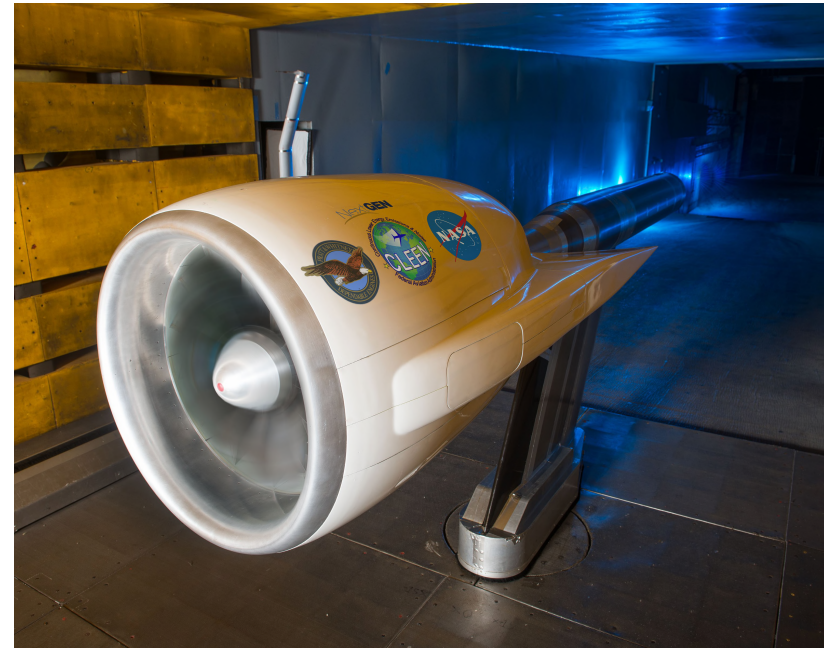
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Key Performance Parameters!

- ! Reduce noise by 15 EPNdB"
- ! Reduce TSFC by 9 percent"

Technology Insertion Challenges Addressed!

- ! Noise reduction & aero performance of advanced liners validated: 1 – 2 EPNdB"
- ! Comprehensive- modern database of propulsor multi-discipline performance characteristics for sys analysis created."
- ! Integrated performance of modern fan + advanced FEGVs + short inlet verified"



Integrated Technology Demonstrator" 2nd Generation UHB Propulsor Integration!

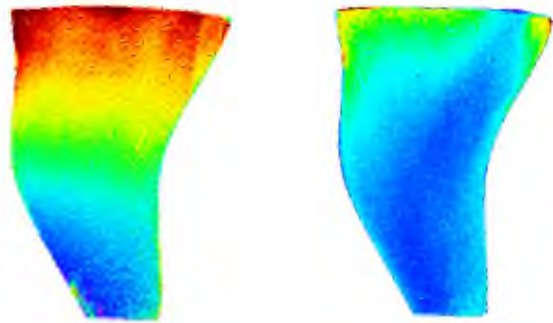


Image Credit: NASA

Pressure & temperature sensitive
paint utilized over range of
operating lines

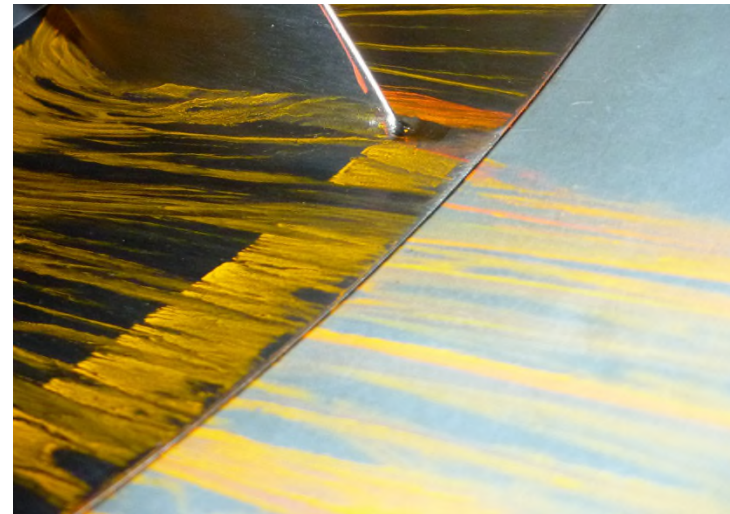
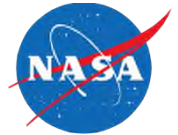


Photo Credit: Pratt & Whitney

Oil pigmentation gave insight
into aerodynamic behavior

ITD35A validated performance and acoustics for the propulsor that exceeded the goals of 9% TSFC reduction and 15 EPNdB noise reduction for the technology.!

Integrated Technology Demonstrator" Fuel Flexible, Low NOX Combustor Integration!



Weight

Drag

TSFC

Noise

NOx

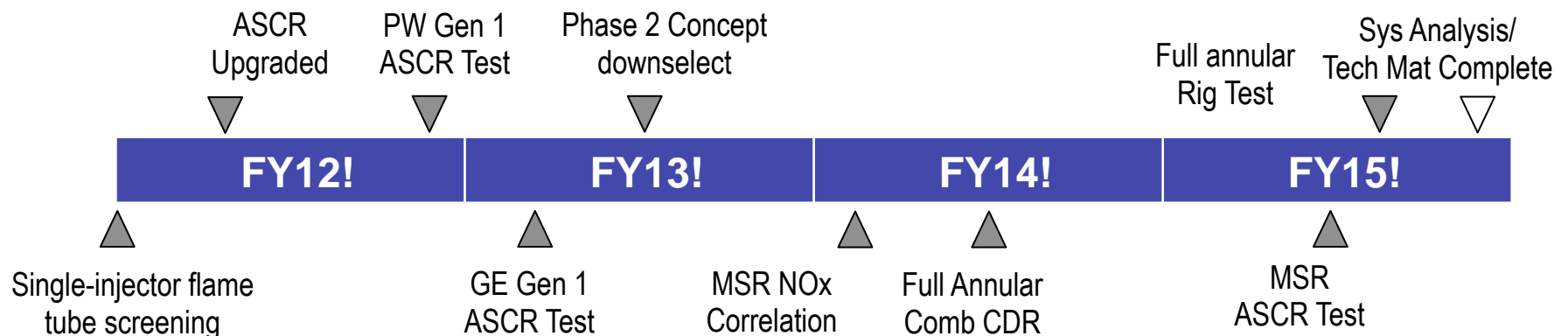
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Key Performance Parameters!

- ! Reduce LTO NOx by 75 percent"

Technology Insertion Challenges Addressed!

- ! Lean burn system operability concerns"
 - ! Auto-ignition"
 - ! Flame stability"
 - ! Acoustic resonance"
- ! Durability for lean burn configuration"
- ! 50/50 jet/alt fuel mixture"



Integrated Technology Demonstrator" Fuel Flexible, Low NOX Combustor Integration!

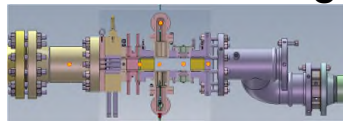


Single Sector



United Technologies
Research Center

AAC Rig



CE5 Rig

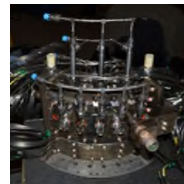


Multi-Sector



United Technologies
Research Center

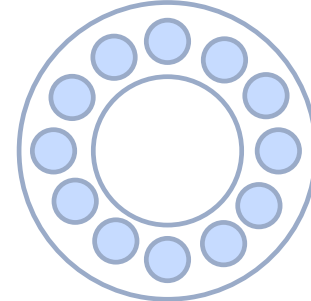
Arc Sector
Rig



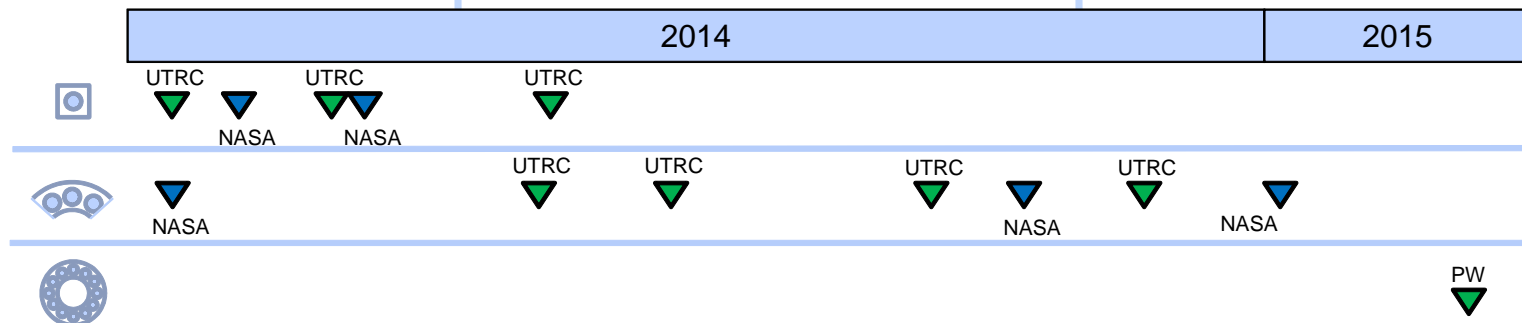
ASCR
Rig



Full Annular



X960 Rig



ITD40A was fully successful in validating greater than 75% NOx reduction re/CAEP6 with a durable lean-lean combustor system that is compatible with alt fuel blends.

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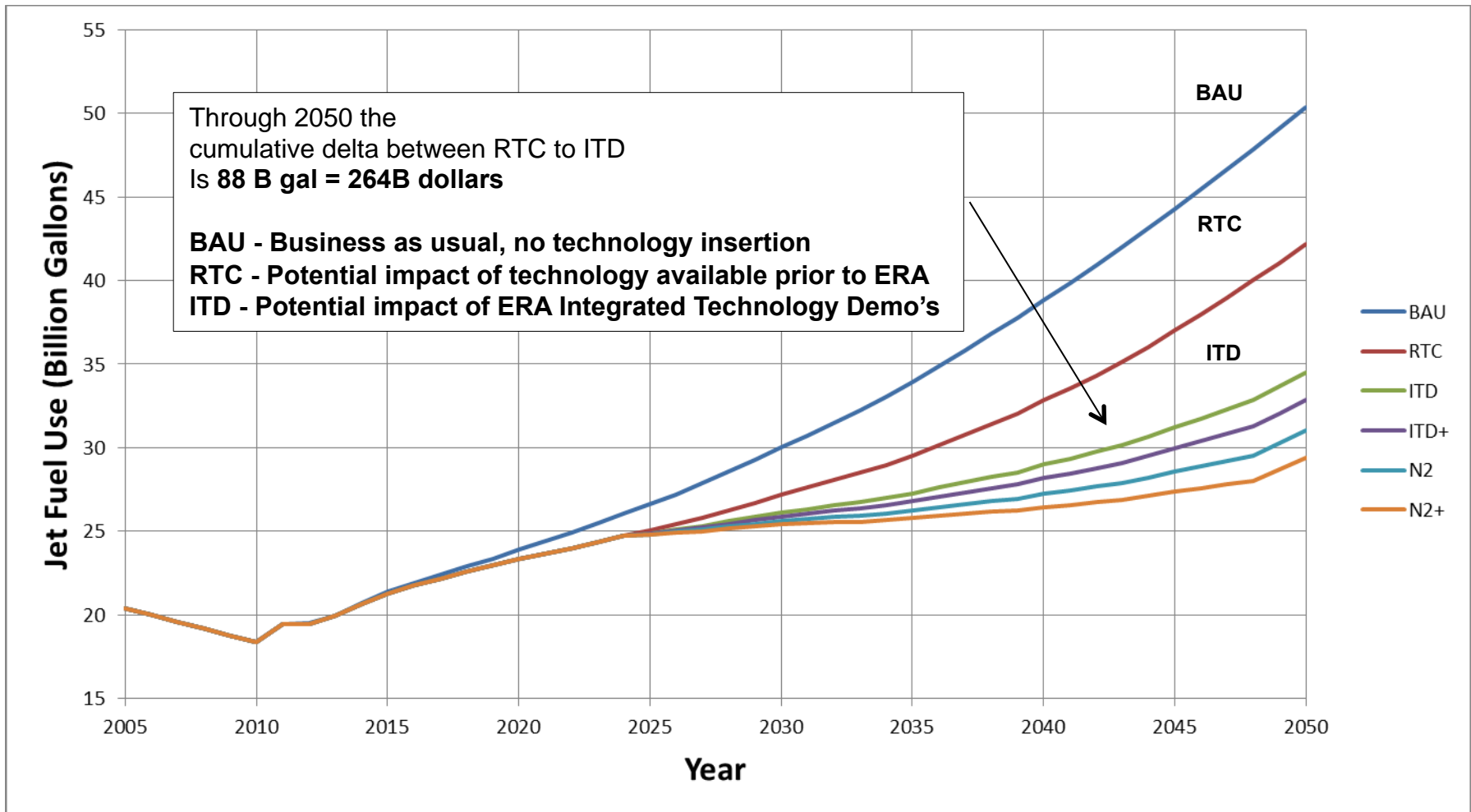


Propulsion Airframe Aeroacoustics research during ERA Phase 1 in partnership with Boeing."

Potential Impact of the Technologies Fleet Level!



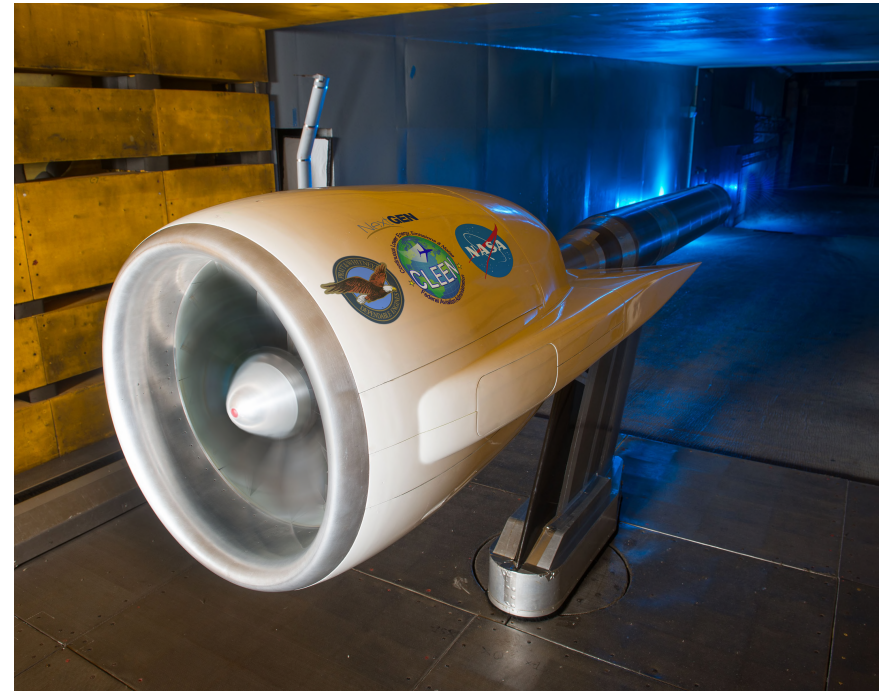
The project is delivering technology that is relevant to next generation aircraft designs and will impact the **carbon footprint** of the fleet"



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2nd Gen UHB Propulsor Integrated Systems Test
in the Glenn 9x15 LSWT (P&W and FAA
CLEEN)"

Closing Remarks!



- ! ERA was a **finite length** technology development project that, in **partnership** with industry and other government agencies, advanced technologies for the simultaneous reduction of aircraft fuel burn, noise and emissions."
- ! The Propulsion Technology ITDs were successful at maturing compressor, propulsor and combustor technologies for next generation engines."

